

Vicarious calibration of VNIR/SWIR bands of ASTER

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Introduction



- Background of ground-look calibration approaches
 - Difference between vicarious calibration and radiance validation
 - Motivation for calibration/validation
 - Overview of approaches for vicarious calibration
 - Description of reflectance-based approach
 - Test site overview
- Reflectance-based results for ASTER
 - Effects of solar irradiance models
 - Comparison with MODIS and ETM+ results
- Cross-comparison data
- Conclusions



Vicarious Calibration



Vicarious calibration is a radiometric calibration approach that does not rely on sensor-based devices

- The goal is to determine the relationship between incident spectral radiance and the sensor output
 - Independent of on-board calibrators (solar diffusers and lamps, for example) and pre-flight calibration
 - Deep space looks, lunar-based calibrations
- Radiance validation is similar but it assumes that the calibration is already known
 - Preflight or onboard calibration gives the radiometric calibration and thus reported sensor radiance
 - Independent method predicts radiance at the sensor
 - If the predicted radiance matches the sensor radiance to within the uncertainties of the two methods, the sensor radiance is validated



Why bother with vicarious?



Radiance validation is most critical for the accurate retrieval of geophysical parameters from temporal data sets with little to no overlap

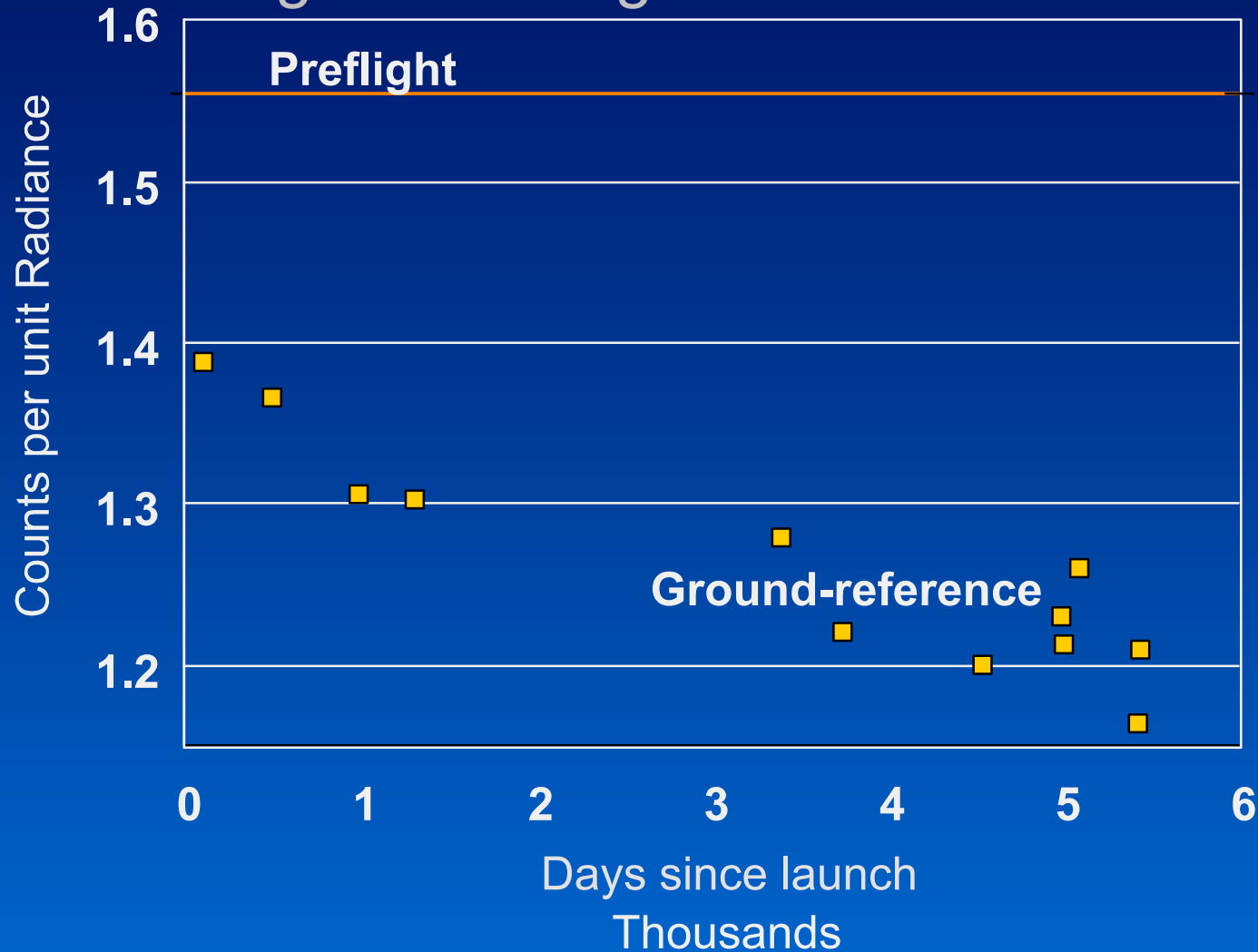
- Realistically, absolute radiometric calibration may not be needed for some specific cases
 - Data from a single sensor with focus on change analysis
 - Multiple sensors for which significant overlap exists
- Temporal studies and inter-sensor measurements, however, critically require validated sensors
 - Biases between sensors need to be removed
 - Temporal changes in response must be tracked
- Temporal studies using multiple sensors with little to no overlap in data MUST have accurate absolute radiometric calibration



Why bother with vicarious?



Landsat-5 Thematic Mapper results from band 1 show significant degradation after launch





Vicarious approaches



Current approaches for vicarious calibration included terrestrial and extra-terrestrial targets

- Stellar targets have been attempted with mixed results
- Lunar approaches have been successful for several sensors
- Deep space looks
- Ground/water/atmospheric reference approaches
 - Rayleigh/molecular scattering
 - Desert scenes
 - Melting snow fields
 - Sun glint over water
 - Cloud tops



UofA Reflectance-Based



Remote Sensing Group at University of Arizona relies primarily on a reflectance-based approach

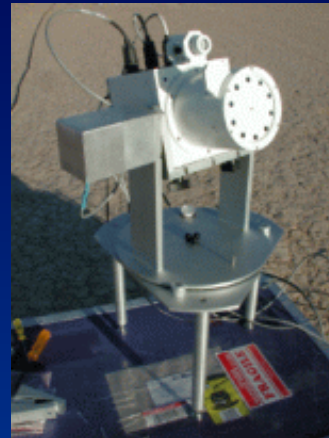
- Atmospheric characterization
 - Aerosol amount
 - Aerosol phase function and single scatter albedo
 - Column absorber amounts (water vapor and ozone)
- Surface reflectance
 - Measurement of a preselected area from the ground
 - Use of airborne or satellite-based sensor
- Input into a radiative transfer code to predict at-sensor radiance
- Band-averaged over sensor spectral response and compared to reported radiance from sensor



Reflectance-Based Approach



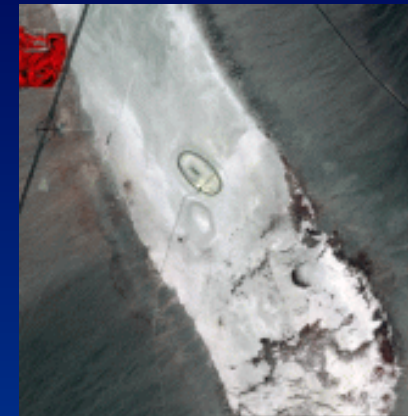
Measured
Surface
Reflectance



Measured
Atmospheric
Parameters

Radiative Transfer Code

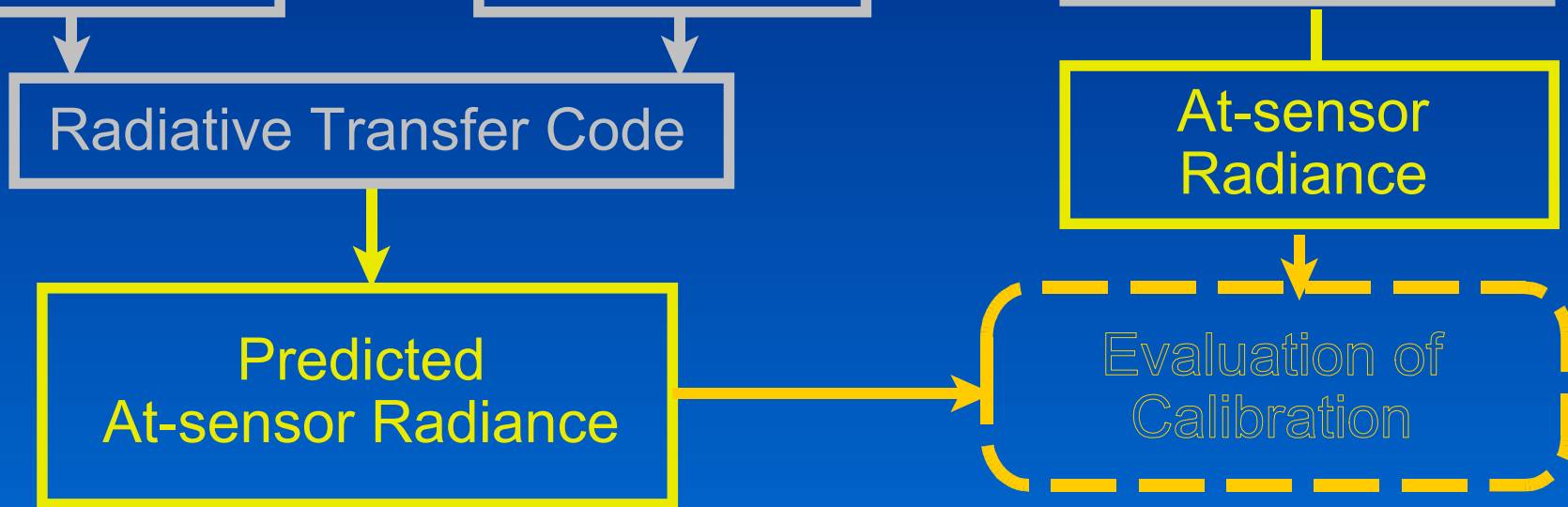
Predicted
At-sensor Radiance



Average Test Site
Output from
Imagery

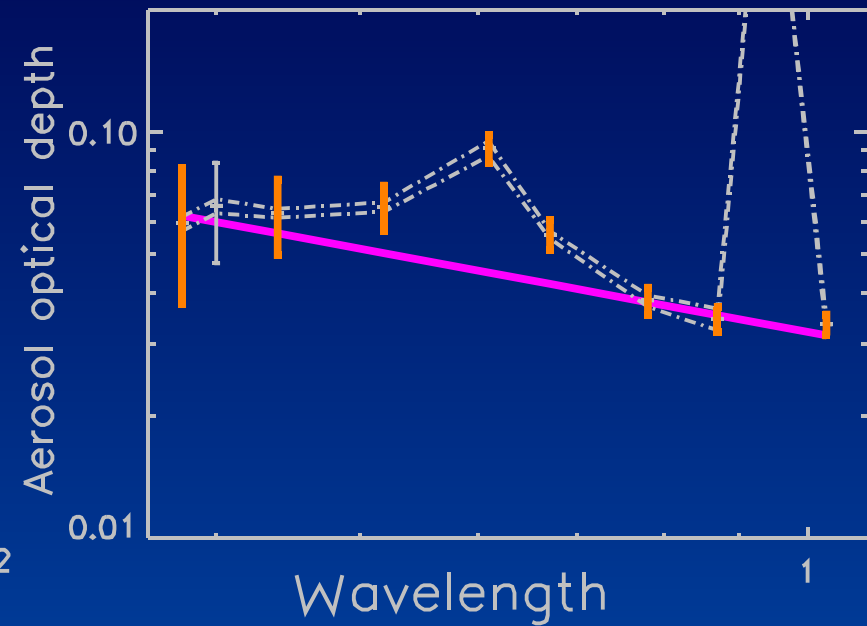
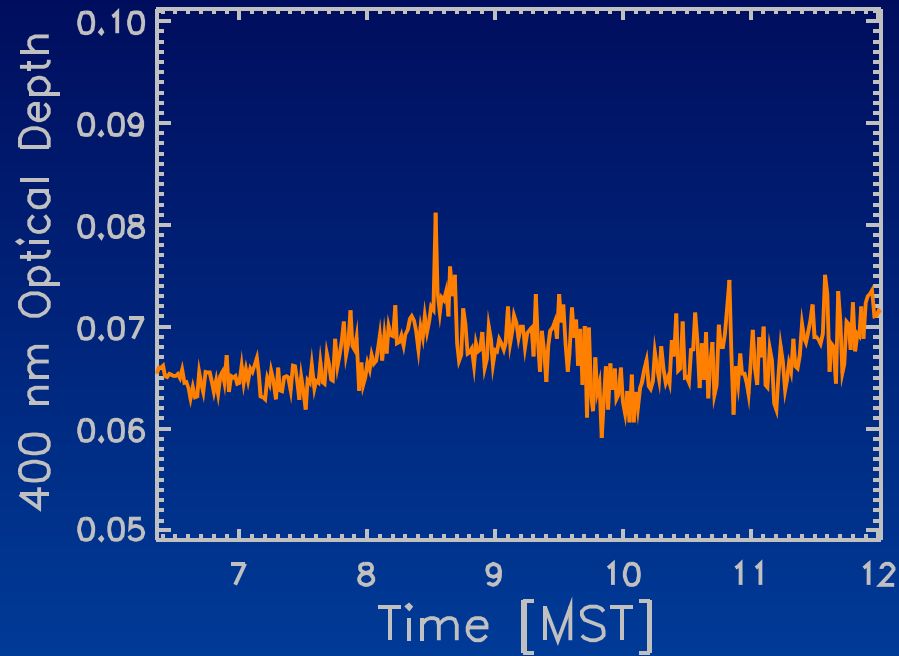
At-sensor
Radiance

Evaluation of
Calibration





Atmospheric Measurements





Surface reflectance



Measure a large area of the test site related to numerous pixels of the test sensor

- Measurements of the upwelling radiance of the test site are referenced to a standard of known reflectance
- Standard is characterized in the RSG's laboratory
- Instrument is a commercially available spectrometer



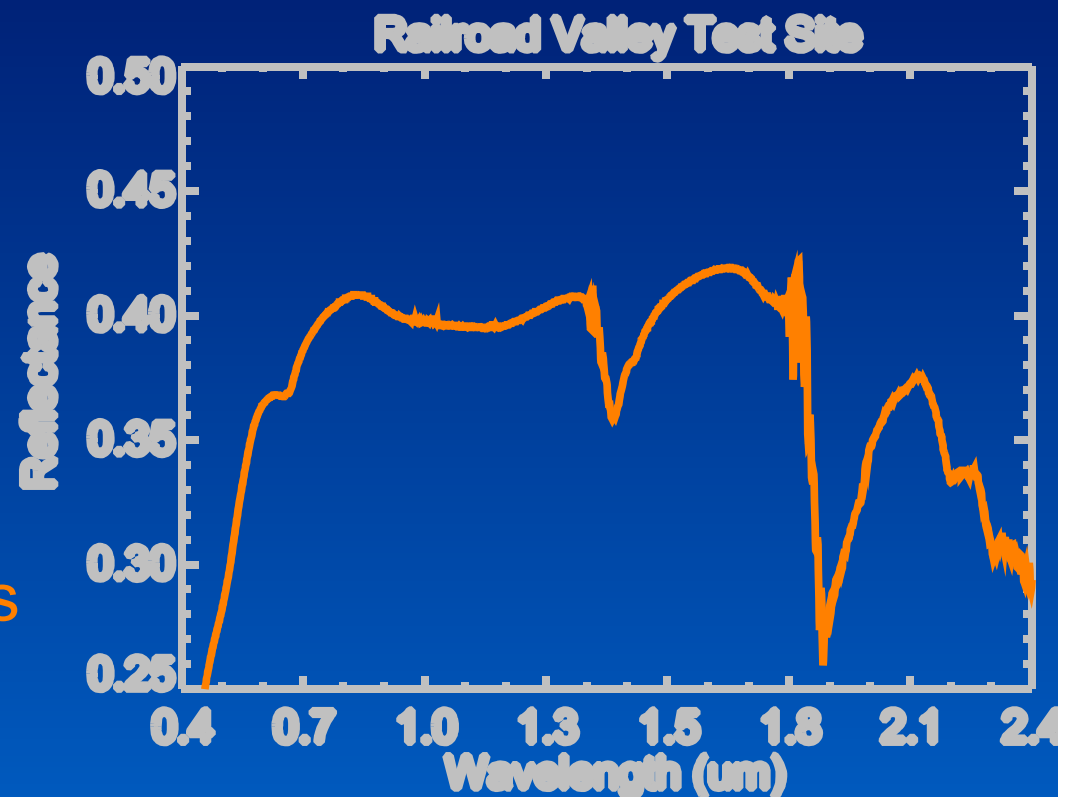


Surface Reflectance



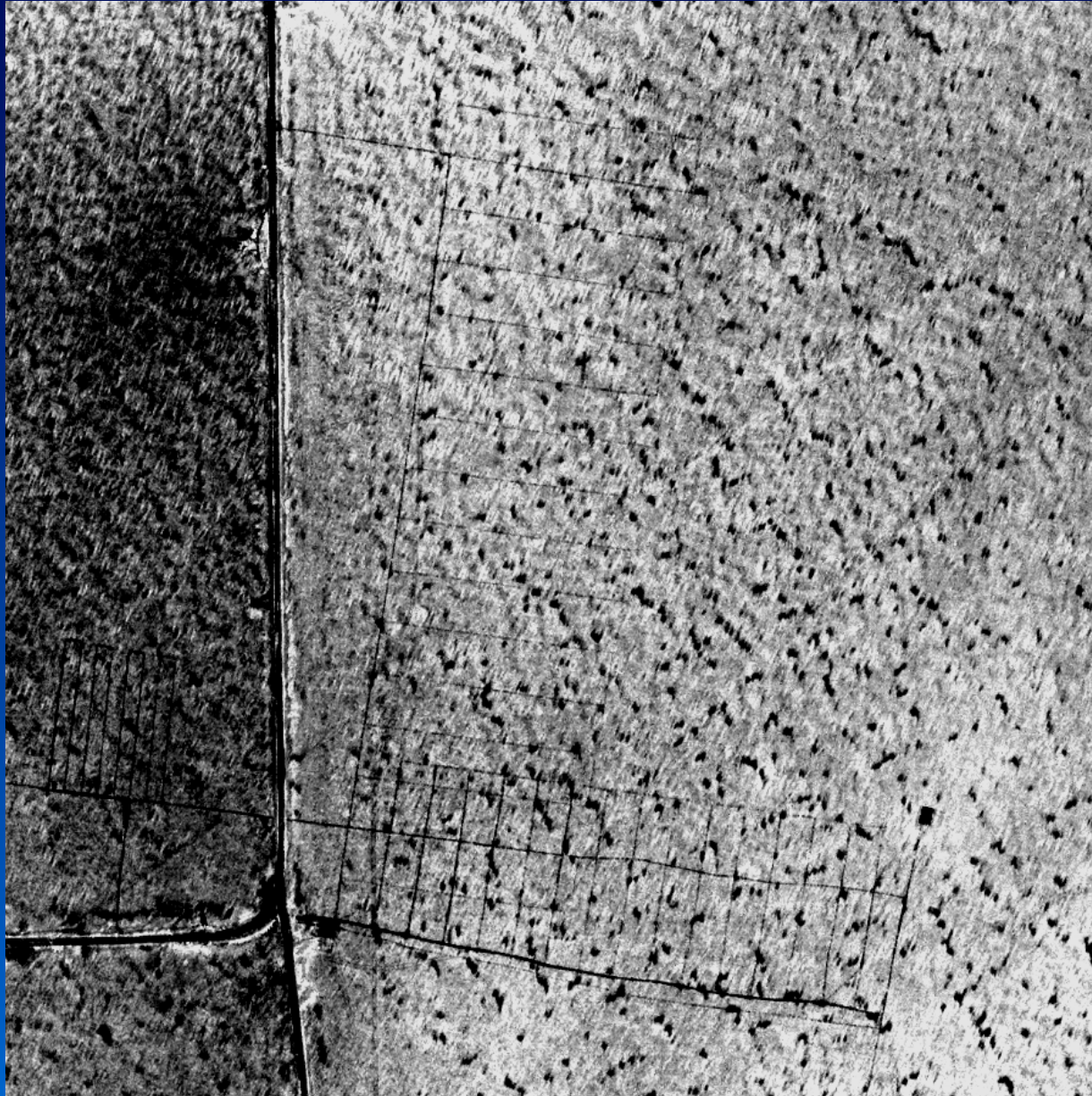
Spectral reflectance is the average of all data points collected over the entire site

- Area covered is 300 m by 80 m
- Takes approximately 30 minutes to collect the data set
- 480 spectra that are averages of 20 samples are collected
 - 8 spectra per 20 m
 - Reflectance standards measured every 64 spectra



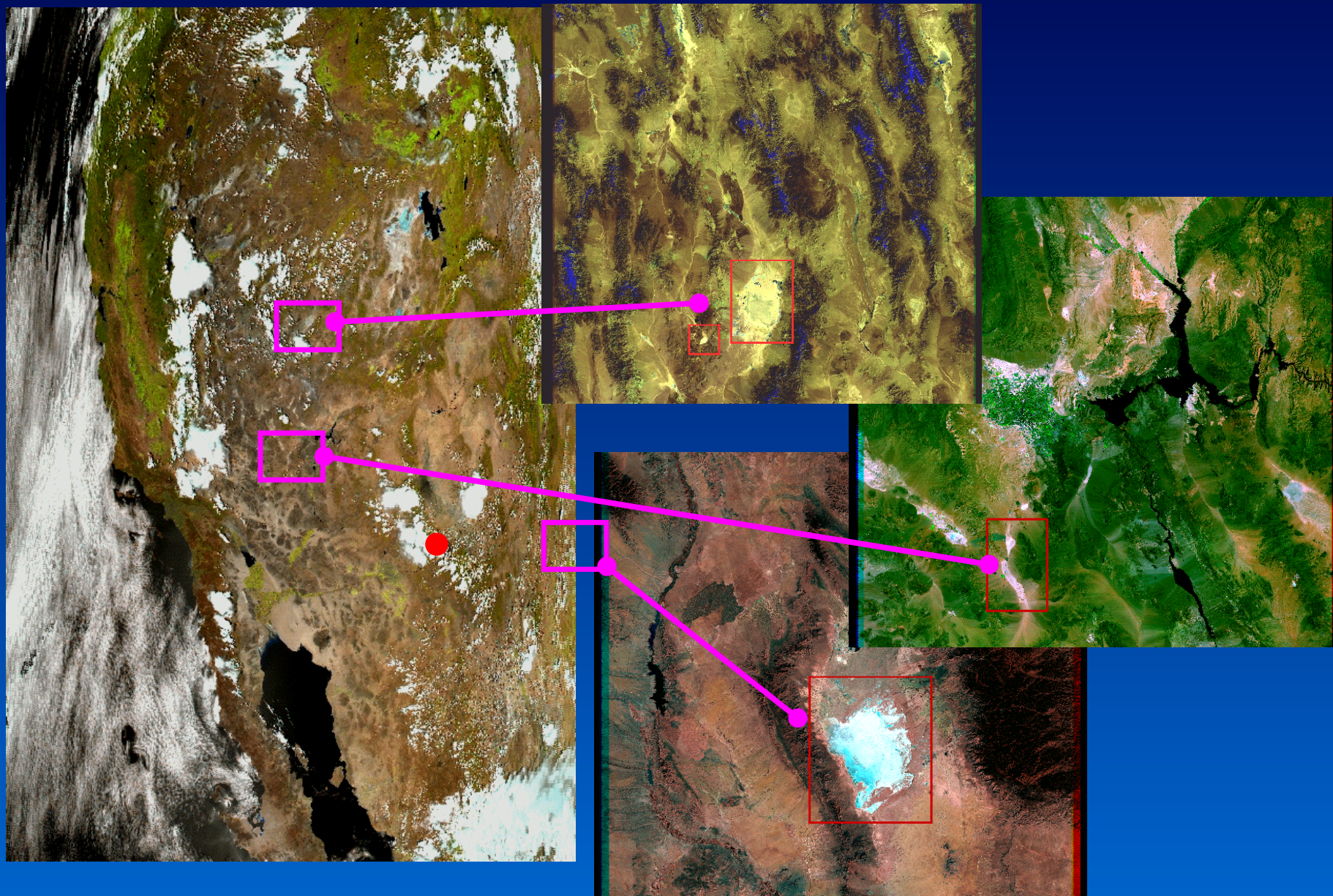


Surface reflectance



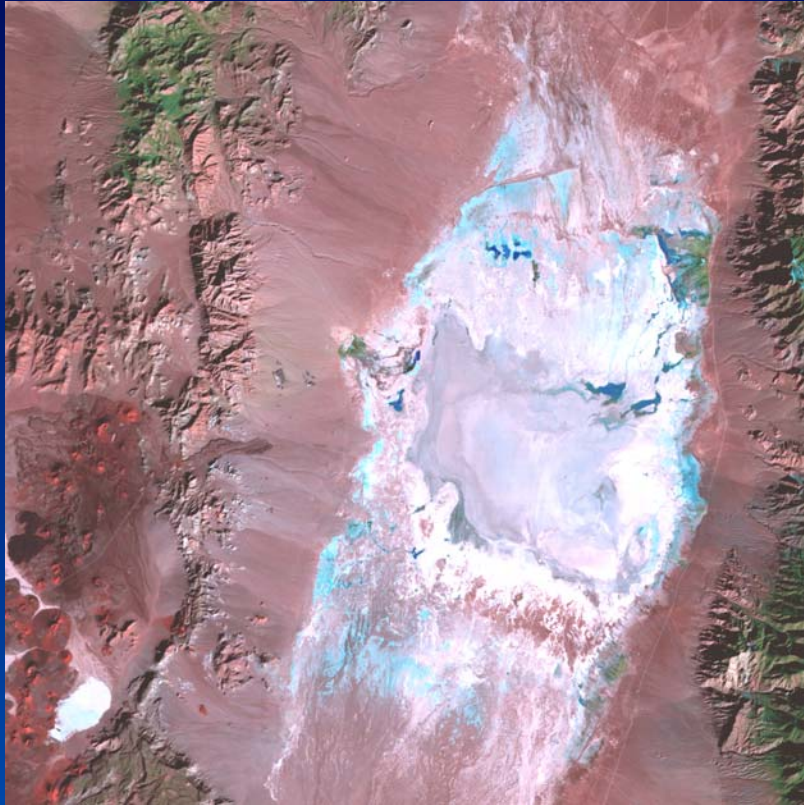


Test sites



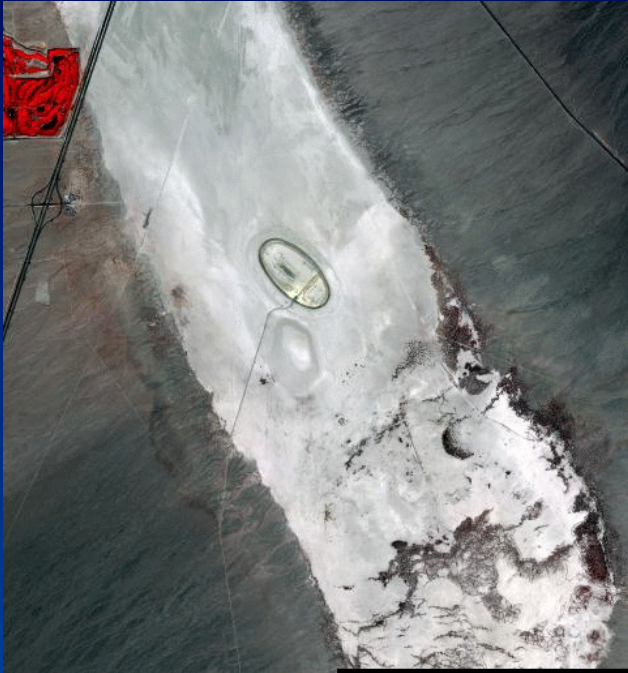


Railroad Valley Test Site



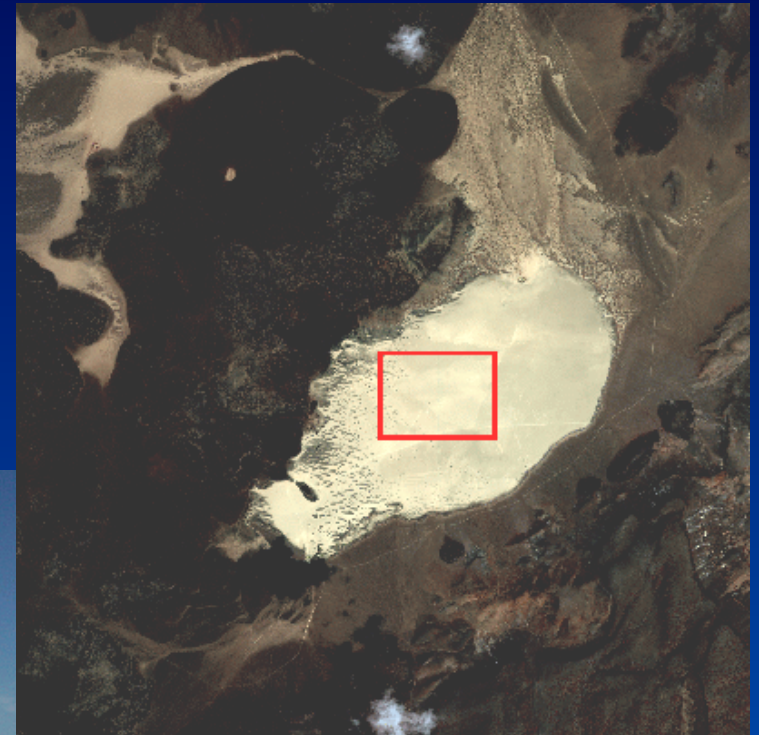


Ivanpah Playa test site



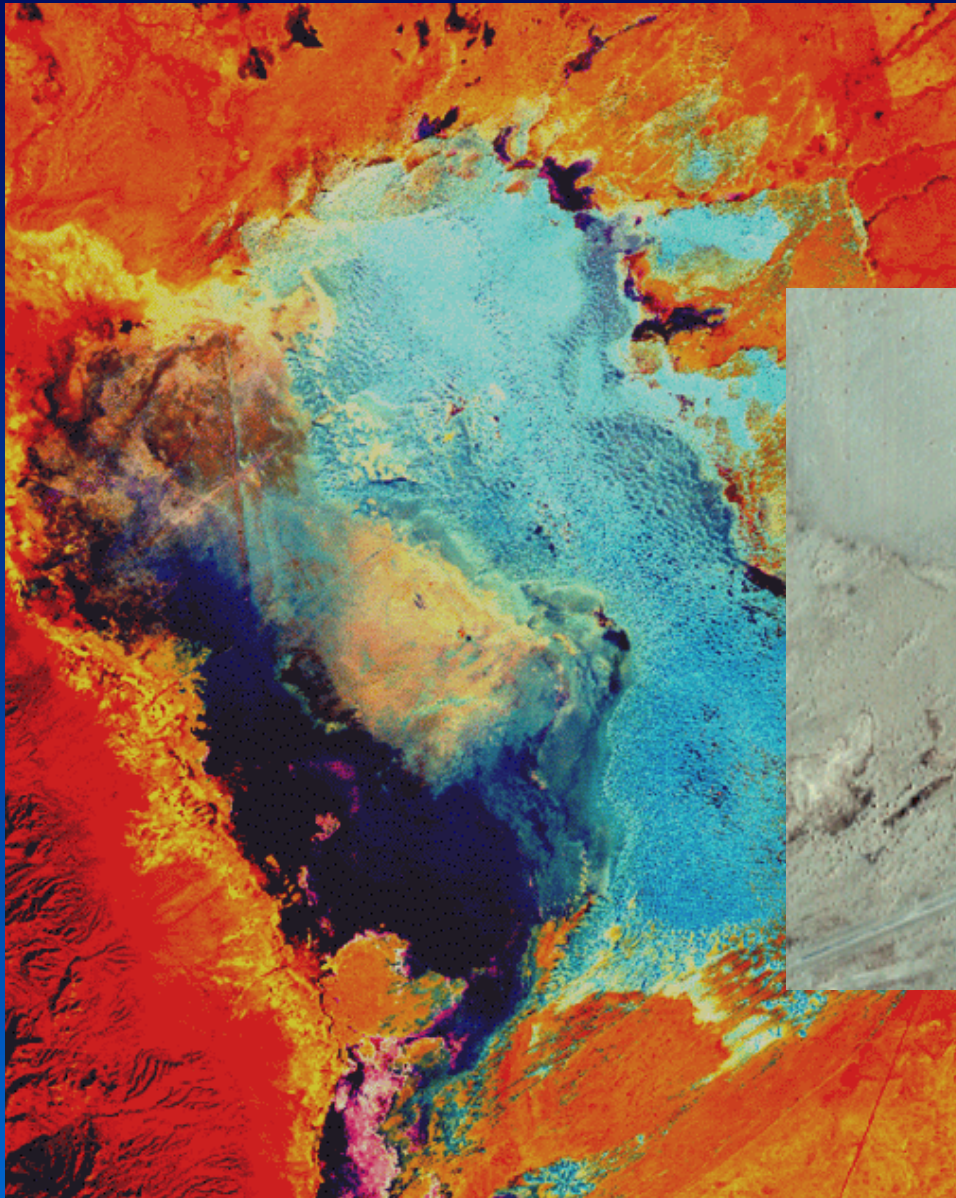


Lunar Lake test site





White Sands test site





Test site characteristics



Test site selection is the most important choice in determining the uncertainties in reflectance-based approach

- Goal is to understand the interaction between the surface and the atmosphere
- Test site characteristics
 - High, flat spectral reflectance and nearly lambertian
 - Large geographic size with spatial uniformity
 - Low aerosol loading (high elevation)
 - Accessible and historical understanding of site
- Other choices such as radiative transfer code, aerosol model, instrumentation are also important
 - However, consistency of these will give good precision
 - Site selection will more dramatically impact the uncertainties and can increase the importance of the above items

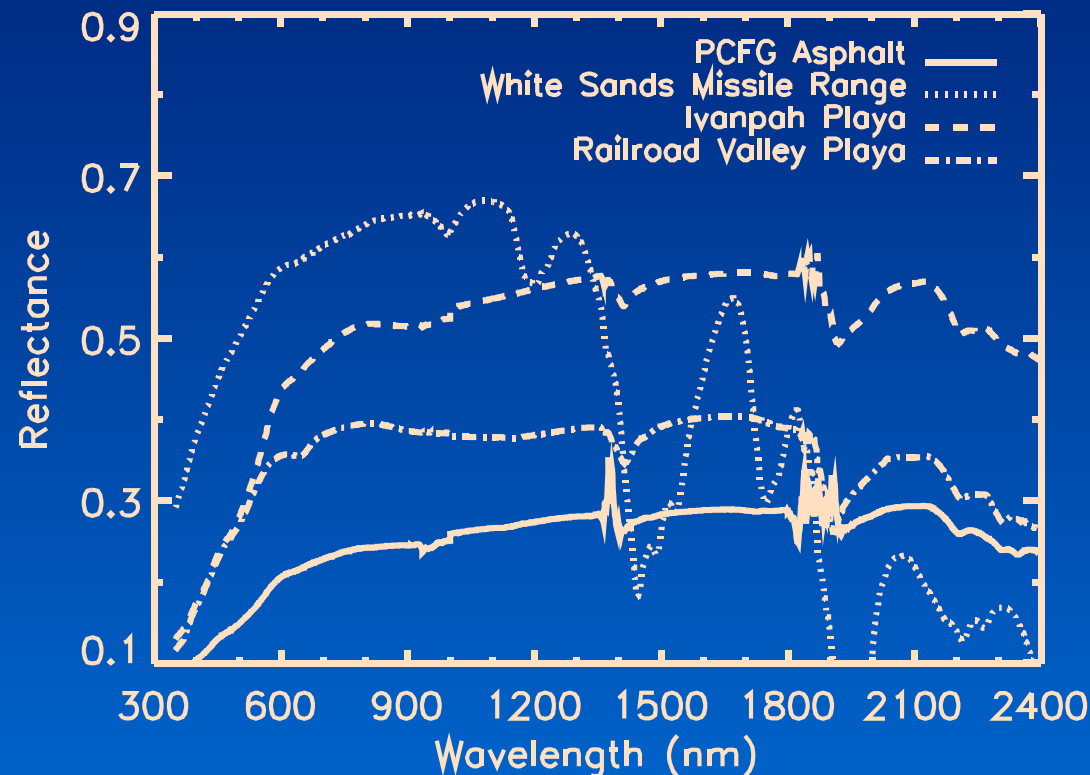


Spectral reflectance of test sites



Ideal surface is flat spectrally

- Removes uncertainty due to lack of knowledge in the sensor spectral response
- Allows for a direct comparison of sensors without spectral corrections

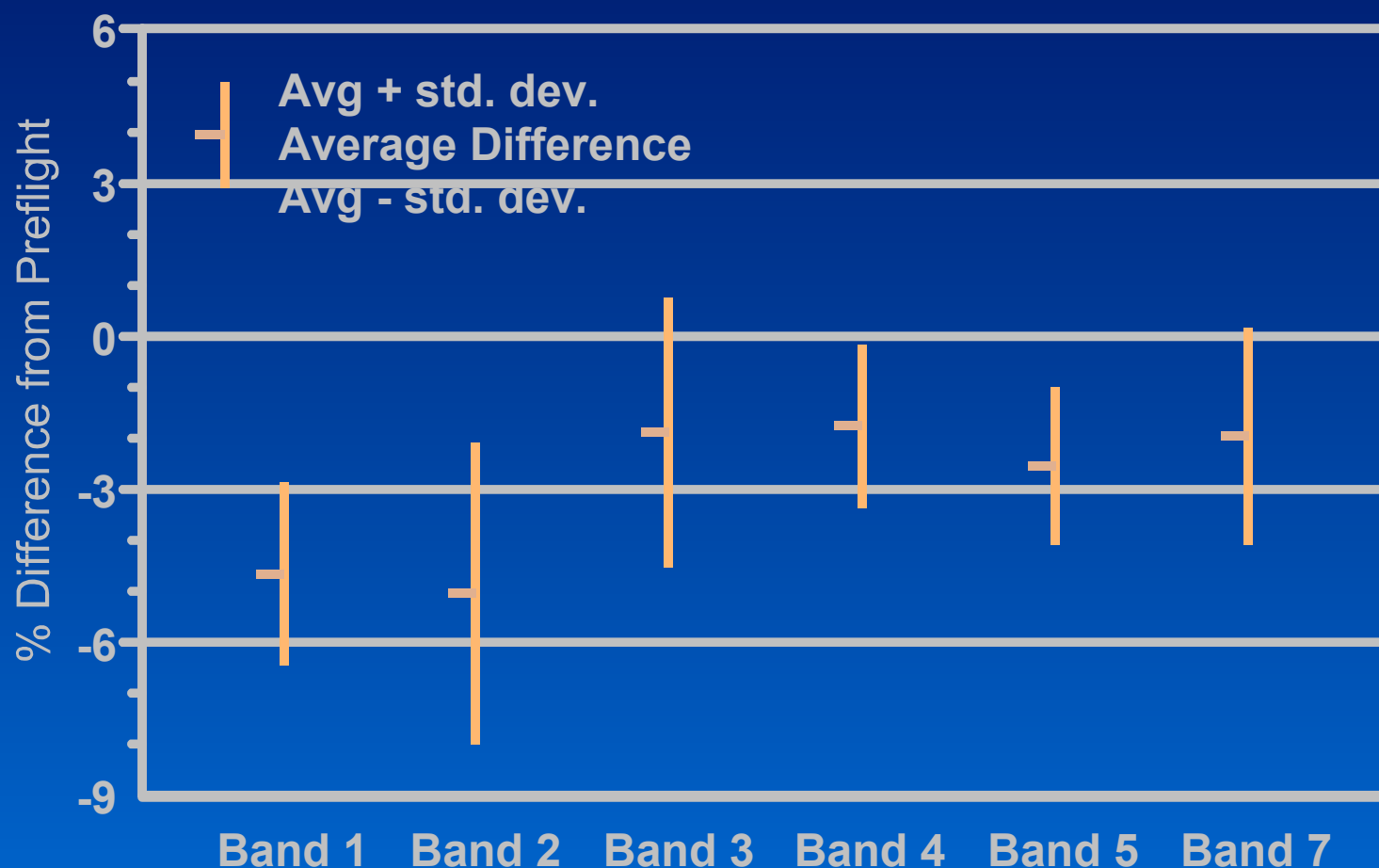




Recent results - ETM+



Radiometric calibration of ETM+ has been shown to be stable since launch using both the radiance validation and onboard calibrators





ASTER Reflectance-Based Results



Evaluate ASTER calibration using both the Level 1B and the Level 1A data sets

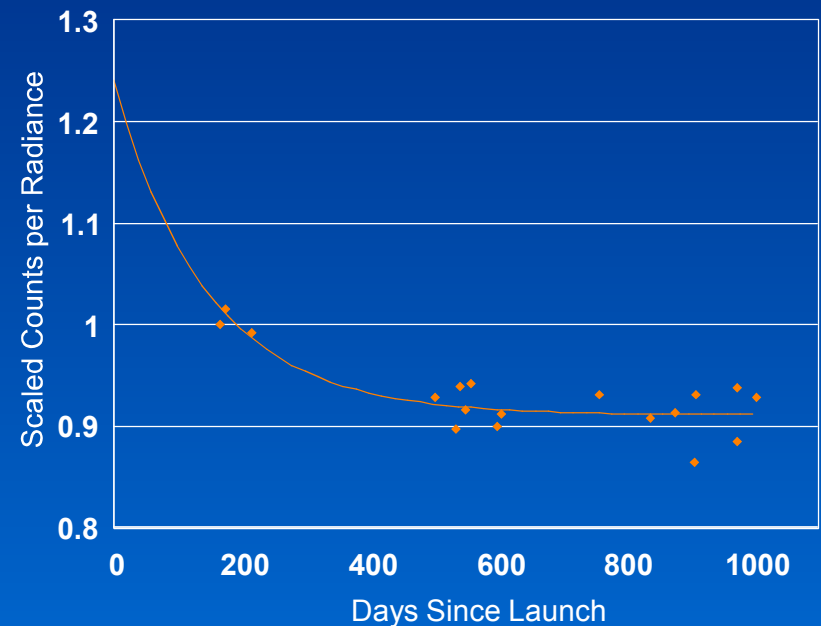
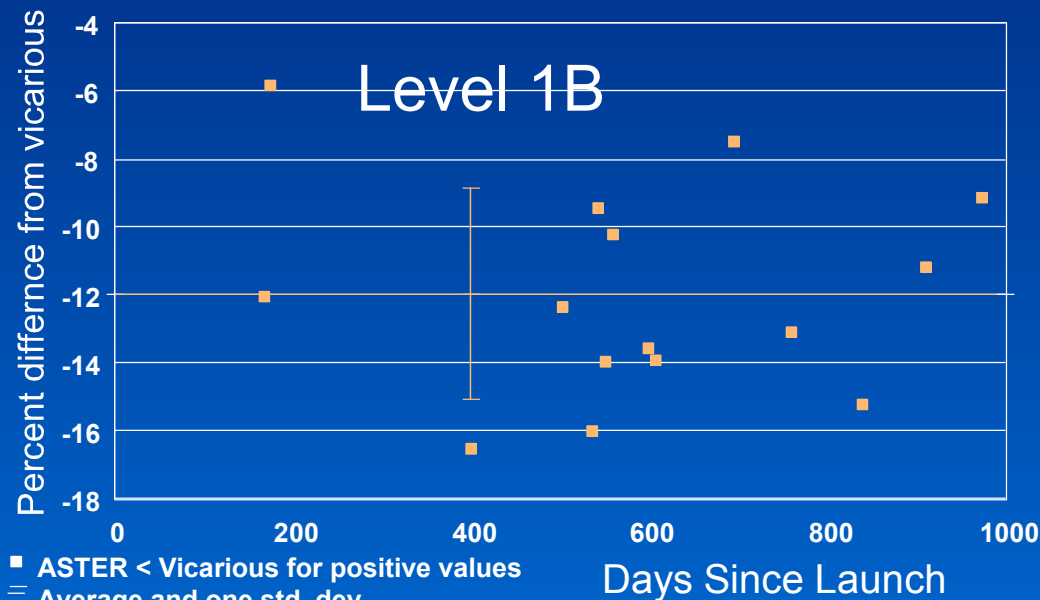
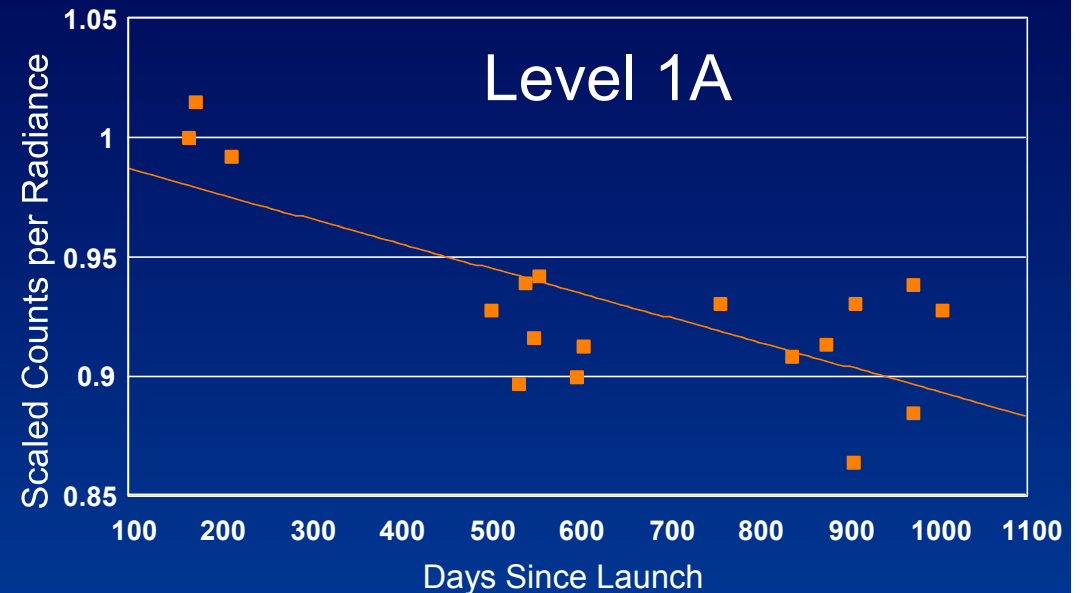
- The comparison to the Level 1B data indicates the absolute accuracy of the radiometric calibration
 - Level 1B data have been radiometrically corrected
 - Rescaled to allow conversion to radiometric units
- Level-1A data analysis allows us to evaluate the trend of calibration
 - Determine the degradation of the sensor to better understand its radiometric properties
 - Understand how well the onboard calibrators are operating
- Level 1A data are examined using the ASTER output (counts) compared to predicted radiance from the vicarious method



ASTER Band 1



- Level 1B data do not show a strong temporal signal but do show a significant bias
- Level 1A data do show a degradation that appears to have leveled out recently

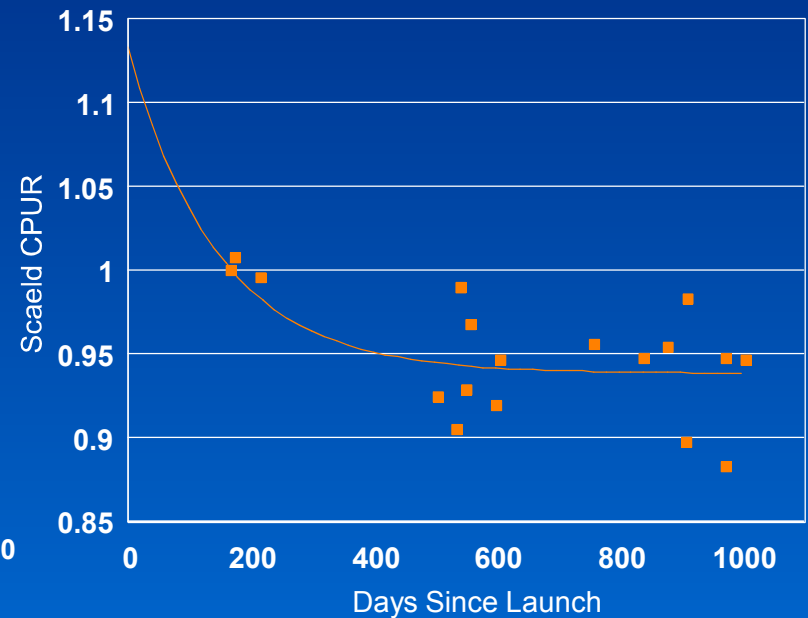
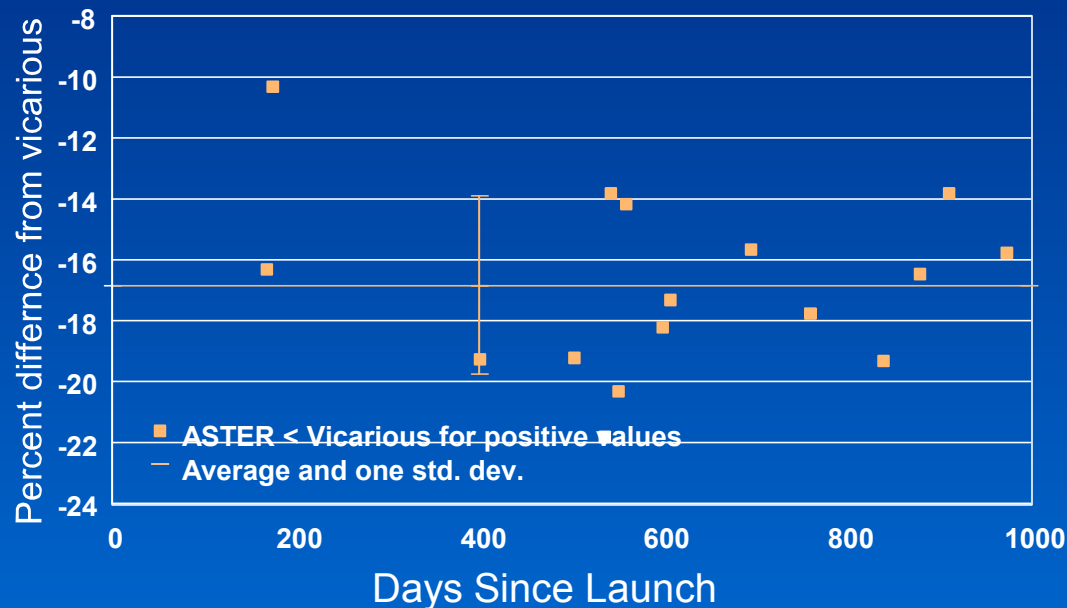
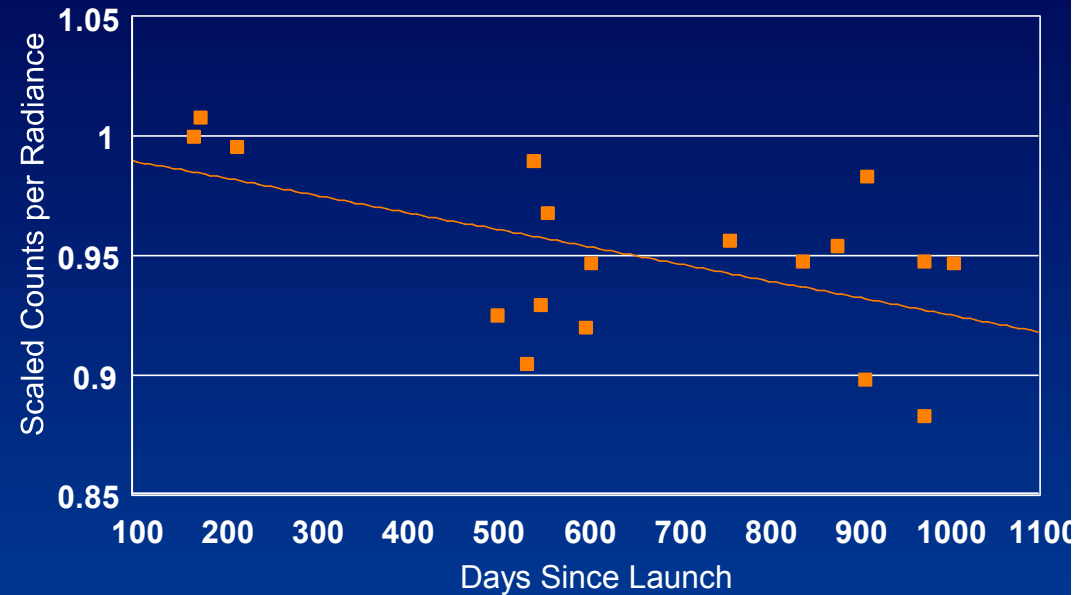




ASTER Band 2



- Level 1B similar to Band 1 data and do not show a strong temporal signal but do show a significant bias
- Level 1A data do show a degradation smaller than Band 1

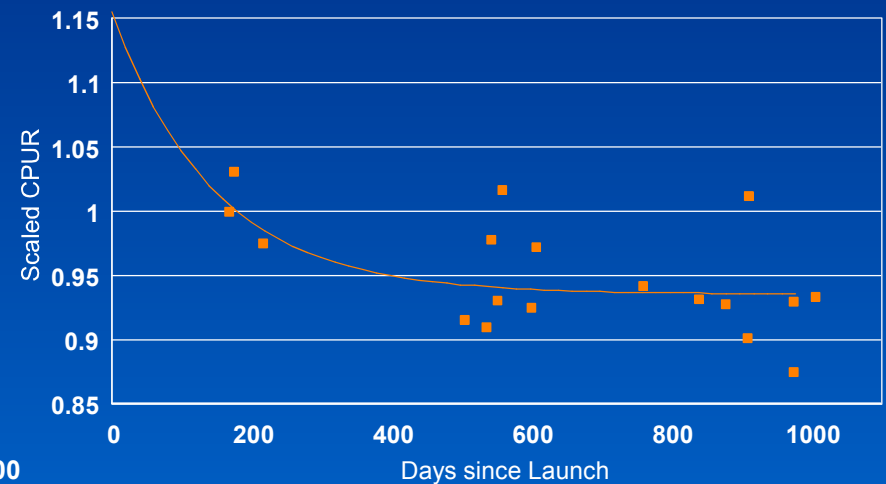
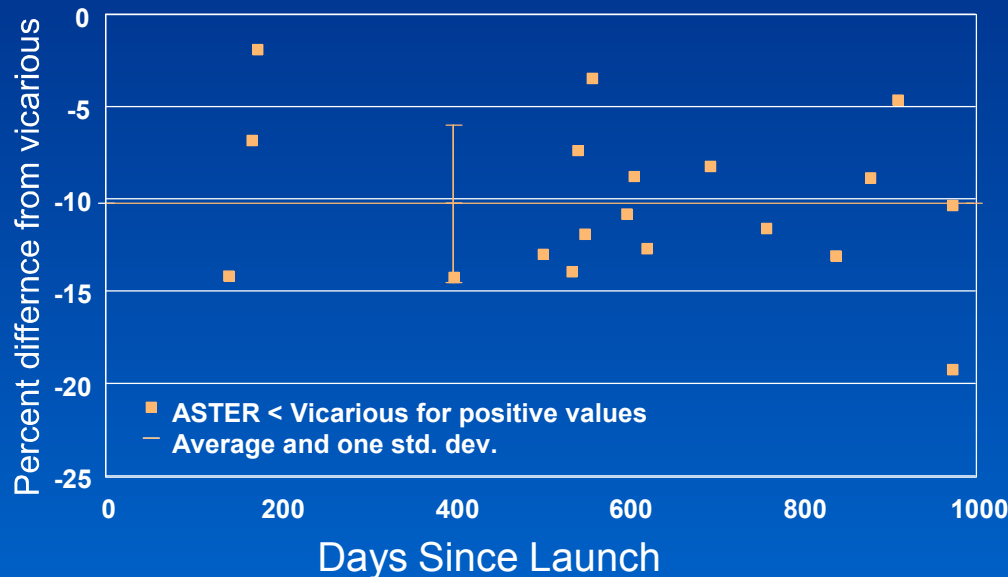
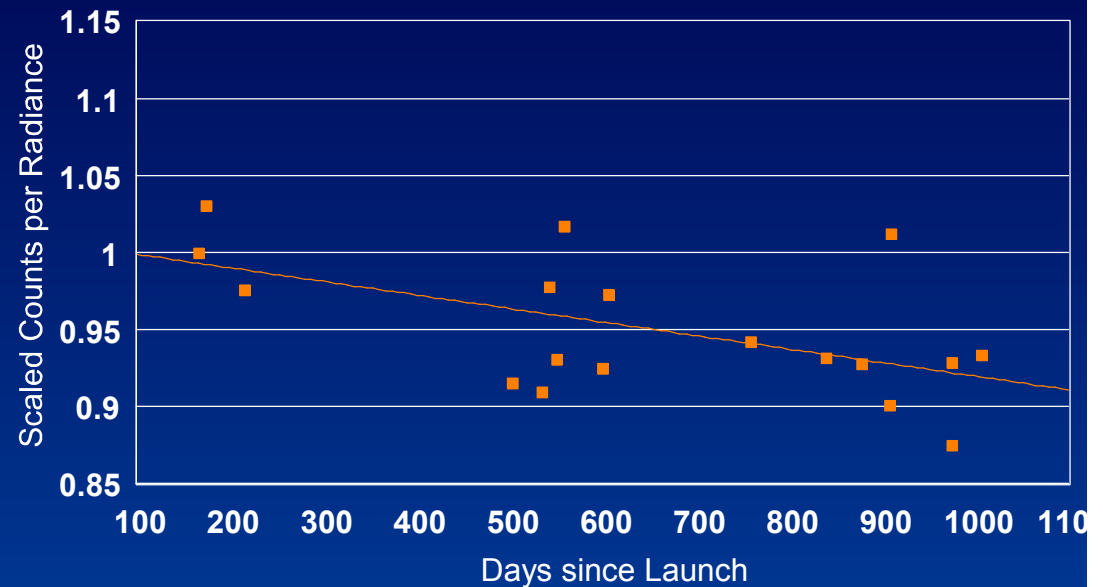




ASTER Band 3



- Level 1B similar to Band 1 data and do not show a strong temporal signal but show a bias
- Level 1A data show a small degradation

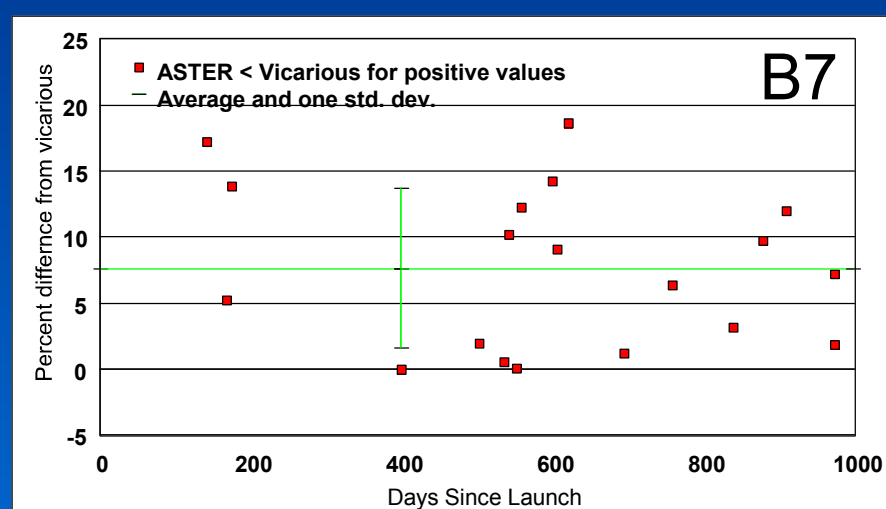
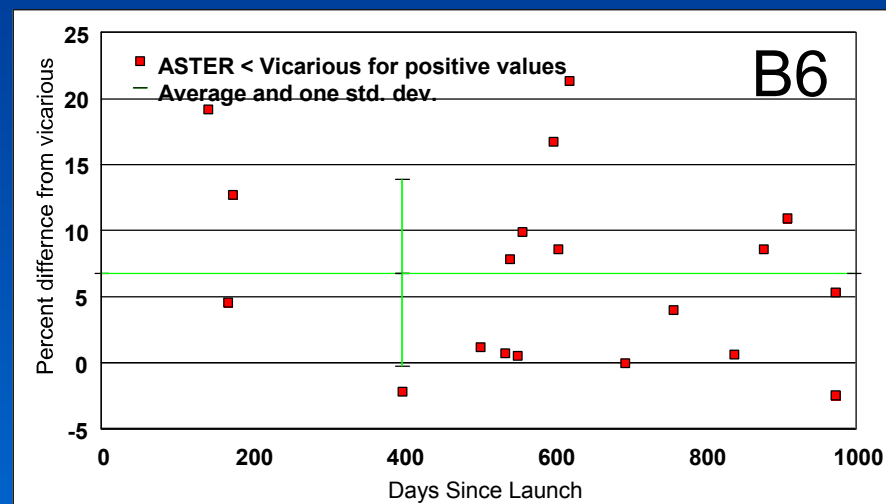
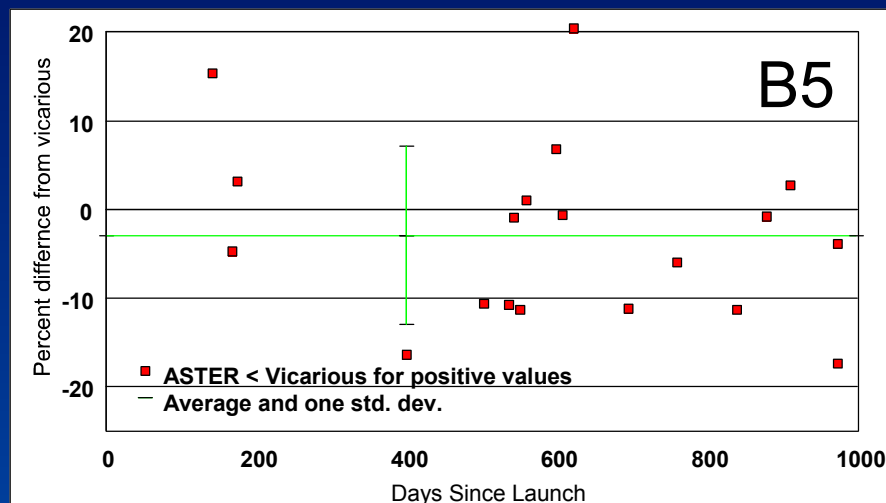
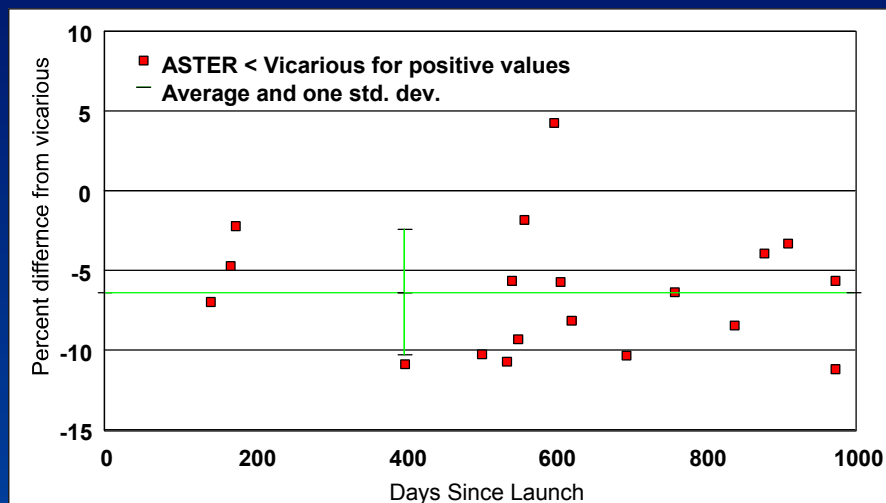




SWIR bands



Graphs below show Level 1B results for Bands 4, 5, 6, and 7



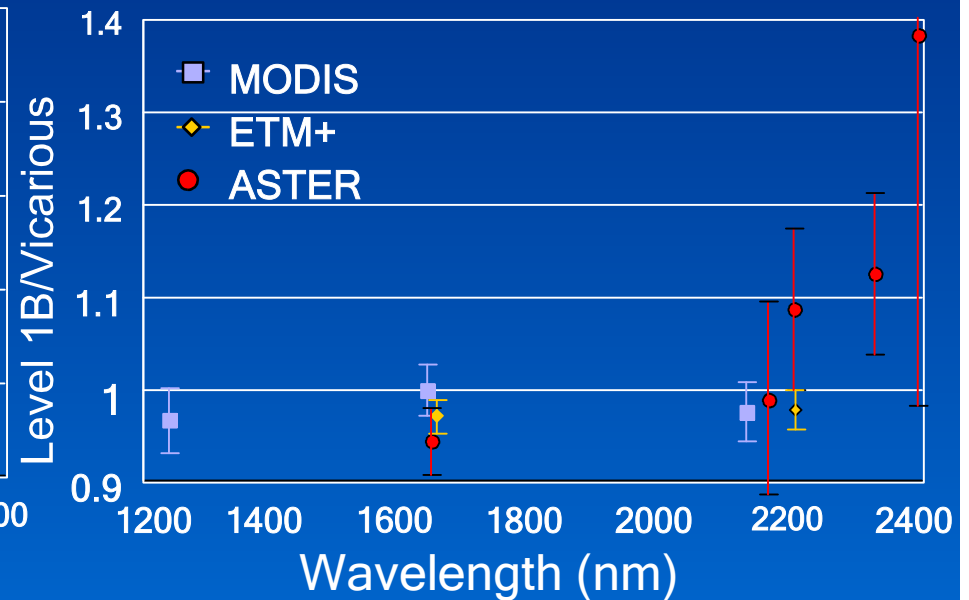
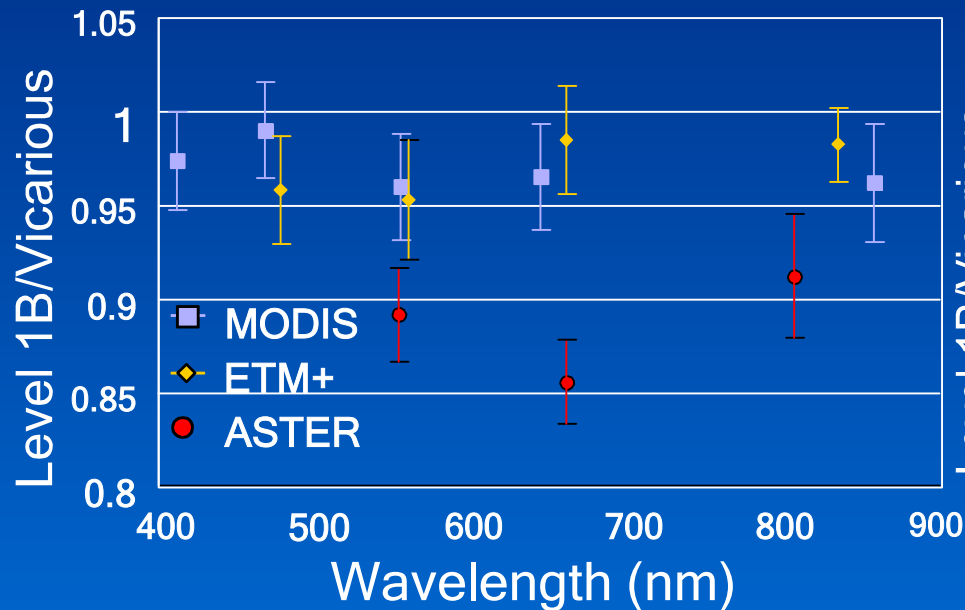


Summary of results



Graphs below show the average percent difference between the vicarious results and the Level 1B radiances

- Results from ETM+ and MODIS are also shown
- Dates are not all identical
- SWIR crosstalk effect is evident
- VNIR bias also visible





Solar irradiance model



A solar irradiance model is used to convert the radiative transfer code results to absolute radiance

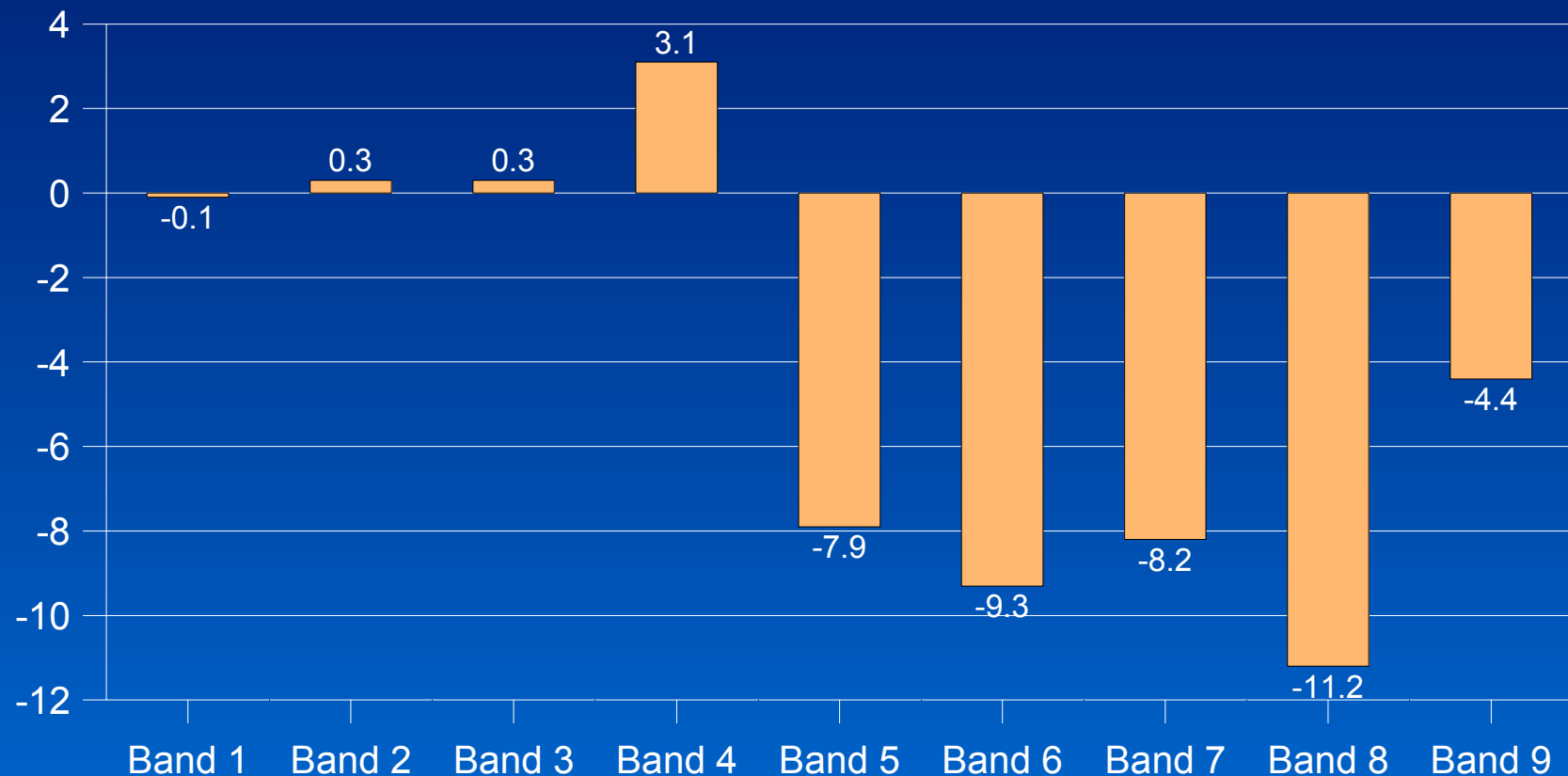
- Selection of solar model has no impact on ASTER Level 1B radiance
 - For ETM+, ALI, MODIS, and others, the solar model is important since these sensors have solar diffusers
 - AVIRIS has “forced” the MODTRAN model to match its laboratory calibration
- The two places where the solar model impact ASTER are in the vicarious calibration and atmospheric correction
- Must have consistency between the vicarious calibration and atmospheric correction if vicarious calibration is used to adjust calibration coefficients
- Will be problems when a user decides to atmospherically correct their own data using an inconsistent solar model



Solar irradiance model effects



- ASTER team uses a solar model called the WRC model
- Typical model used by the community is MODTRAN
- Graph below shows the % difference between the two for ASTER bands

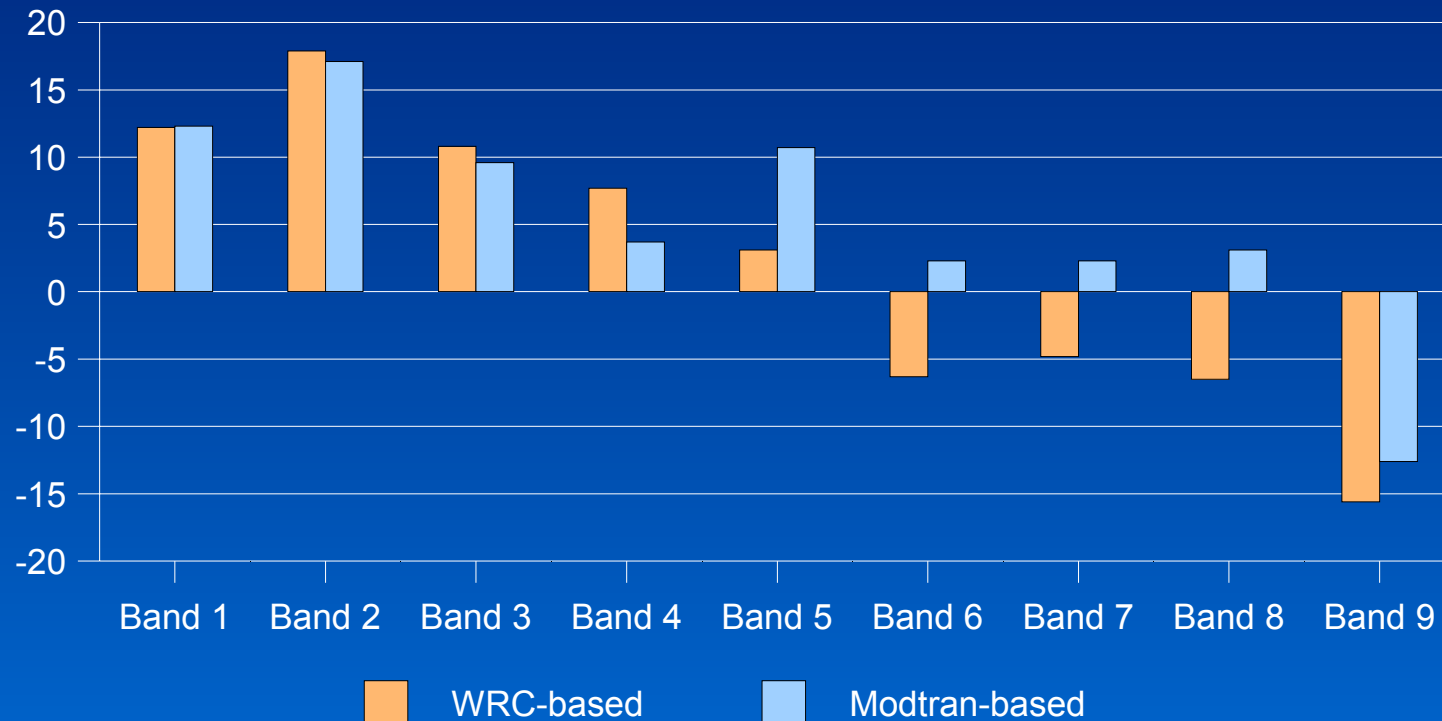




Effect on vicarious



- Graph shows the average percent difference between the vicarious and ASTER data
- Vicarious determined using both MODTRAN and WRC
- Bands 4 and 5 are interesting in that Band 5 is “calibrated” when considering WRC results but not MODTRAN and vice versa for band 4



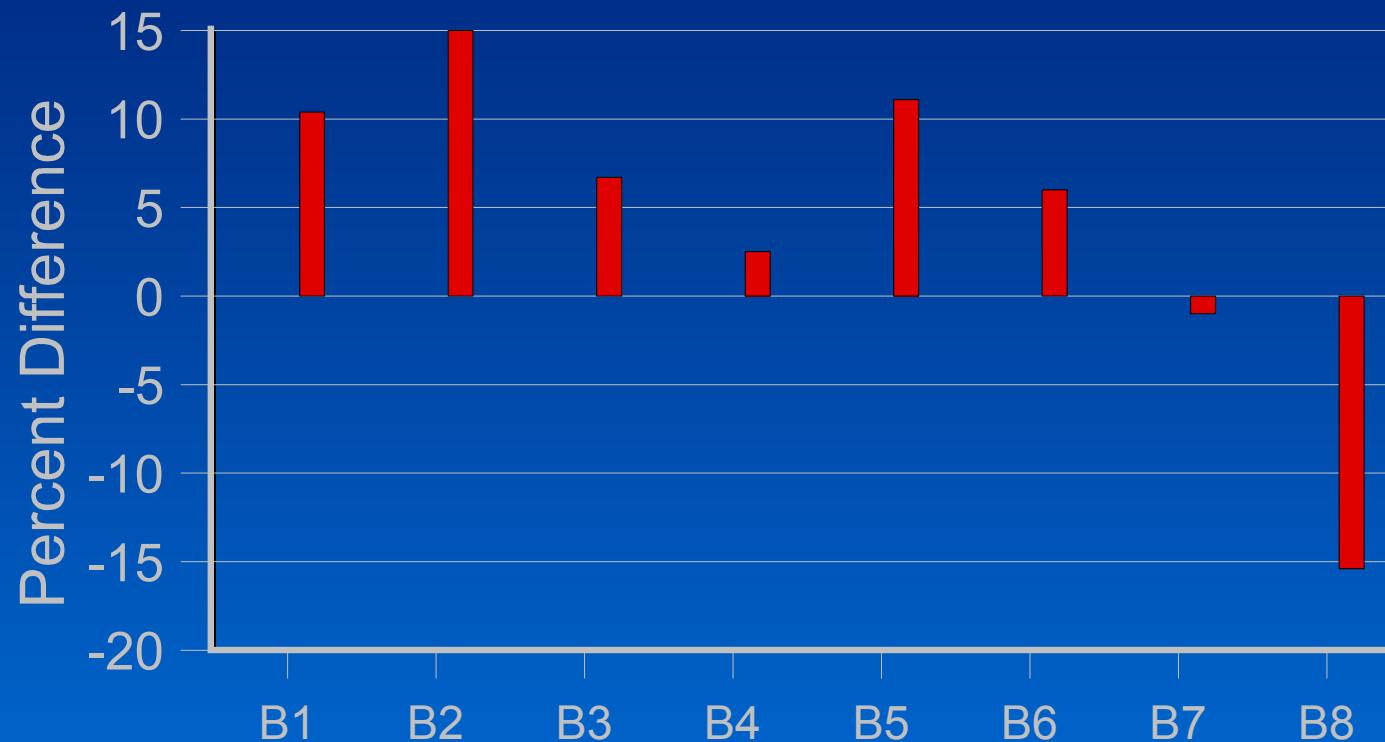


AVIRIS predicting sensor radiance



Shows % difference between AVIRIS & ASTER at-sensor radiances for Railroad Valley -June 30, 2001

- AVIRIS data band-averaged to ASTER spectral response
- Band 9 omitted because insufficient AVIRIS bands to cover full response of ASTER band

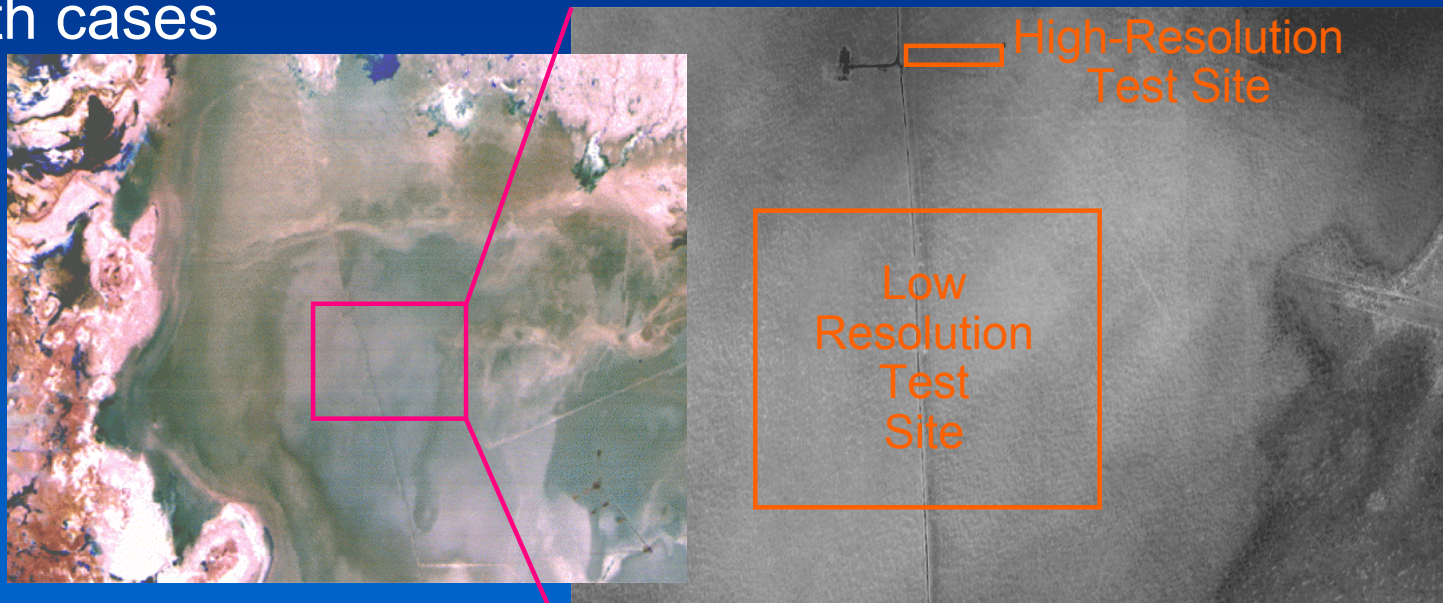




Direct comparison results



- There exist several days of coincident ground data along with MODIS and ASTER data
- Can calibrate both sensors using the same site at RRV playa
 - 1 km² area of Railroad Valley used for both sensors
 - Same radiative transfer code inputs and results
- Dates shown here were from May 16 and June 14, 2002
- Band 1 of ASTER had saturated pixels within the site in both cases



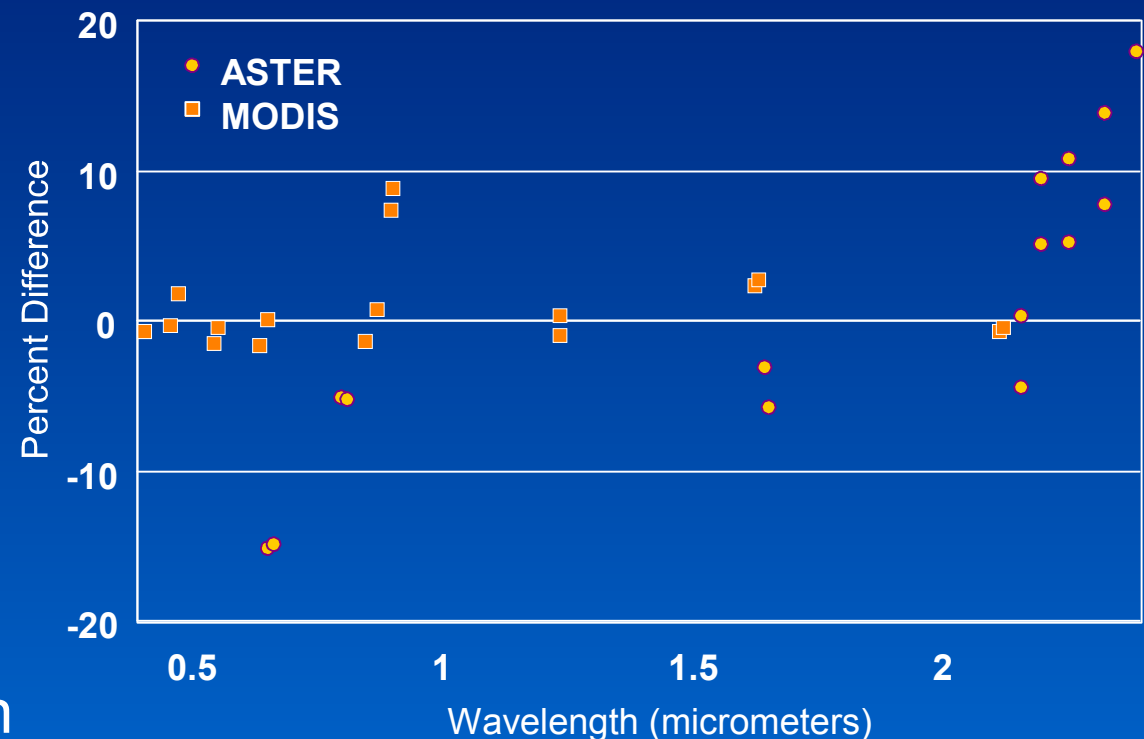


Coincident MODIS data



Using ASTER and MODIS data from the same site for May 16 and June 14, 2002 are shown below

- Both dates show consistent results for MODIS in all bands and for VNIR bands of ASTER
- Band 1 of ASTER was saturated on both dates
- Note the bias is still present in Band 2 and to lesser extent Band 3
- SWIR crosstalk effect also apparent
- Difference between dates in the SWIR is under investigation



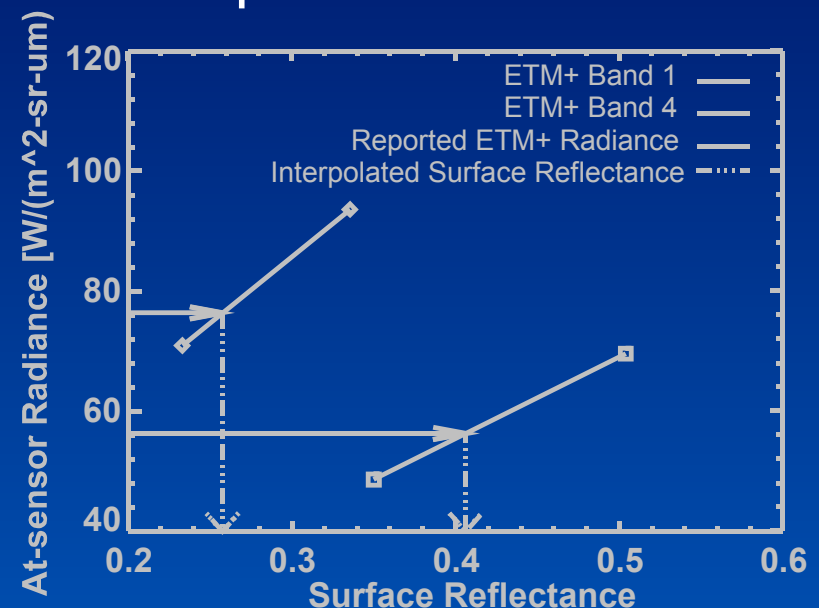


Cross-comparison in reflectance



Can also atmospherically-correct data to reflectance and then compare in reflectance

- Radiance comparisons work when overpasses are nearly coincident
- Other cases require a correction for atmospheric differences and geometry
- Instead compare surface reflectance
- Atmospheric correction based on measured atmospheric conditions as input to a radiative transfer code for two representative reflectances
- Linear interpolation from a known radiance gives the surface reflectance

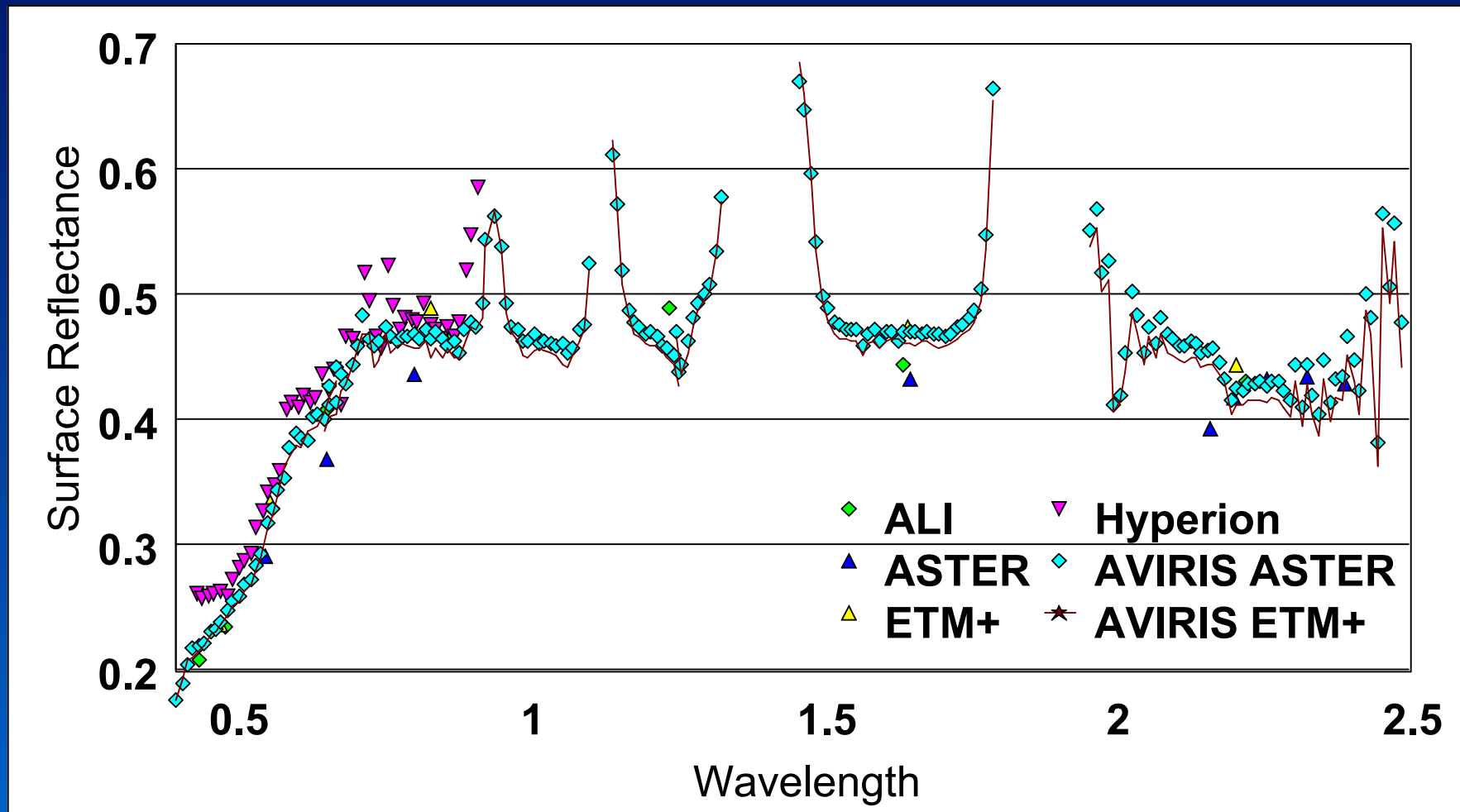




Cross-comparison results



Summary of retrieved reflectance of Argentinian playa (El Leoncito) in Jan. 2001 for given sensors

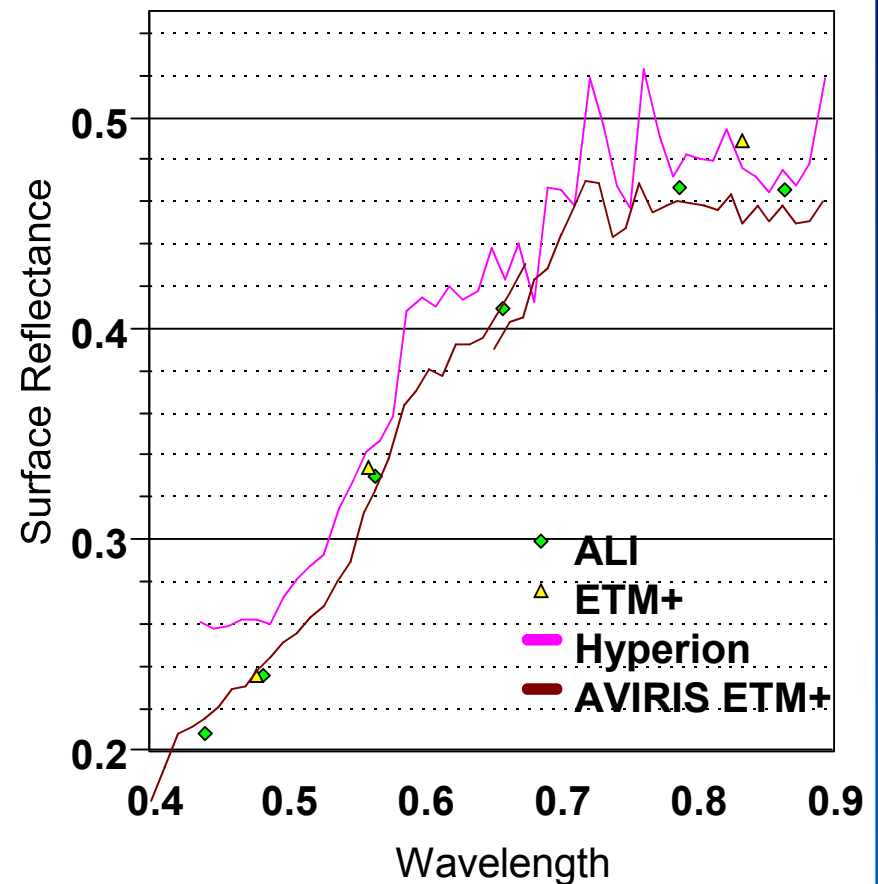
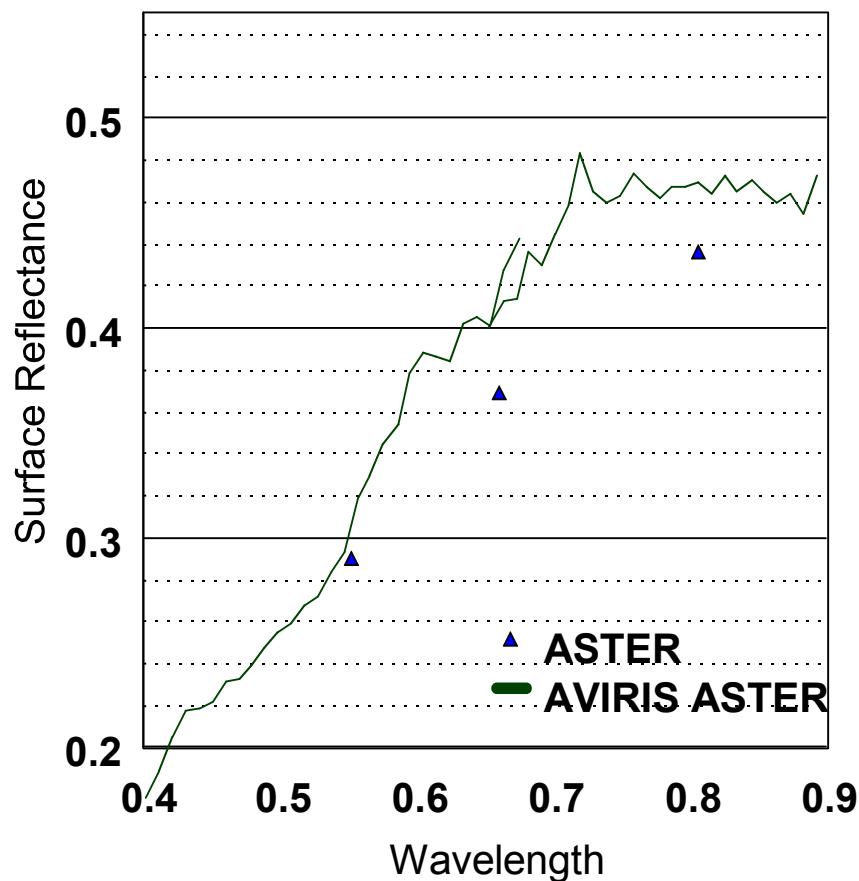




Cross-comparison results



Comparison of VNIR bands for similar overpass times of El Leoncito





Conclusions



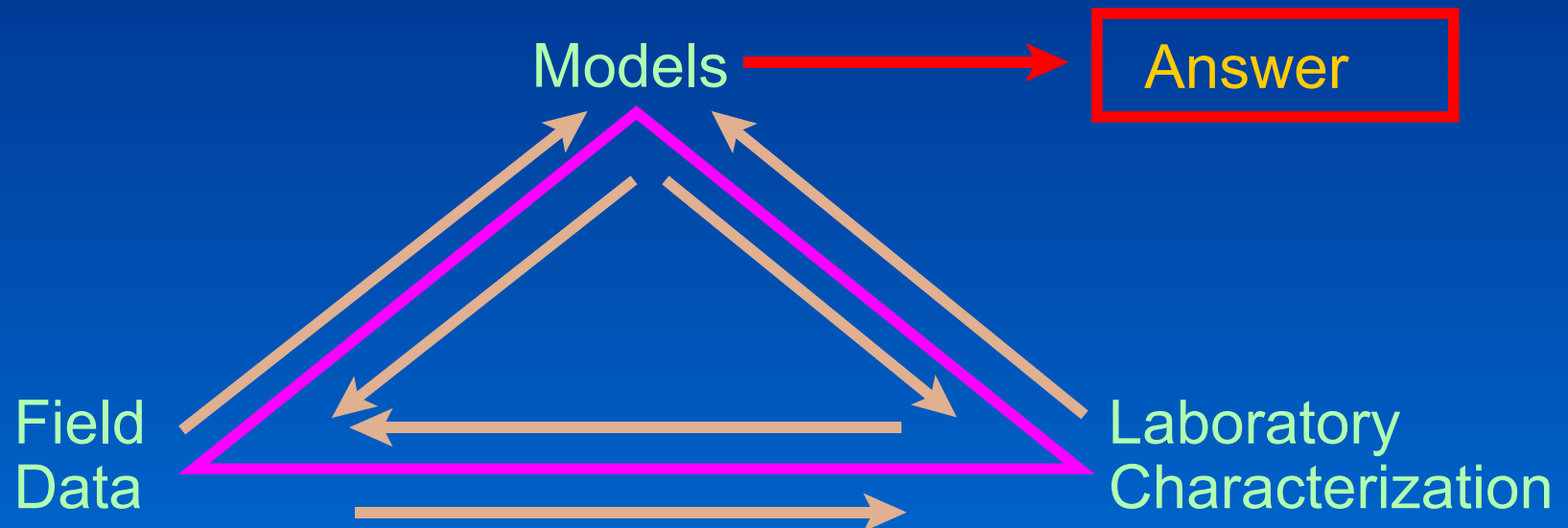
- ASTER VNIR bands
 - Bias in the Level 1B radiance
 - Level 1A results are beginning to diverge from the onboard calibrator results
 - Gaps will be filled with comparisons to MODIS
- ASTER SWIR bands
 - No strong temporal degradation
 - Crosstalk effect is large enough over vicarious sites to cause confusion in interpreting bands 5-9
 - Bands 4 and 5 could be susceptible to error when doing own atmospheric correction
- Cross-comparison to other sensors shows similar results as the reflectance-based calibrations
 - ASTER VNIR bands are not consistent with many other EOS sensors
 - SWIR data require a cross-talk correction



Conclusions



- Reflectance-based accuracy is approaching 3% in visible and near infrared
- Precision is near 2% in the VNIR [$1-\sigma$]
- Further improvements to precision will be found by evaluating all aspects of the problem
 - Understanding of field instrumentation
 - Greater frequency of field collections
 - Evaluations of the radiative transfer codes





Conclusions



- Current level of precision is adequate for trending if done at greater frequency
 - 12 times per year (that's successful collections)
 - Onboard systems provide better frequency and precision
- Improvement in precision allows trending with fewer collections per year
- Once precision is reduced, then it is possible to determine biases
 - Cross-comparison work gains further confidence
 - Apply approach to a greater number of data sets
- These types of data sets as well as others (lunar view, additional sites) will be critical over the next 12-24 months to evaluate the onboard calibrators and crosstalk correction software